APPENDIX K.

Vital Sign Descriptions- *What is this Vital Sign and Why Is It Important?*

Climatic

Vital Sign 1: Climatological Conditions

BRIEF DESCRIPTION: Basic climatological measurements include: temperature (maximum, minimum and average), precipitation, relative humidity, wind (direction and speed), surface pressure and snow cover (depth and water equivalent).

SIGNIFICANCE: Because climate is a basic driver of all ecological systems, these measurements are important for understanding the relationship between climate and other components of biotic and abiotic systems. Without climate data, it is impossible to appreciate the causes of a variety of ecosystem changes—from vegetative cover changes to shifts in aquatic systems. In fact, the most important components of useful climatological measurements are the length and accuracy of the data. Maintenance of climate stations, therefore, is extremely important in order to assure high-quality data.

PROPOSED METRIC: Temperature (maximum, minimum and average), precipitation, relative humidity, wind (direction and speed), surface pressure and snow cover (depth and water equivalent)

RANK: overall 5, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Automated weather stations with satellite up link. Frequency: generally hourly average, max, and min

LIMITATIONS OF DATA AND MONITORING: Mesoscale and network applications may require modeling based on meager high elevation and coastal data sets.

CURRENT MONITORING: KATM and ANIA lack any type of weather station within their boundaries. KEFJ has one NWS COOP weather station located near Exit Glacier and LACL has weather stations at Stoney Strip (RAWS) and in Port Alsworth (RAWS, NWS COOP). A detailed evaluation of all climatic monitoring in southwestern Alaska has been completed: http://www.nature.nps.gov/im/units/swan/Documents/Maps/SWAN_WeatherStationAssessment.pdf

In FY04 a cooperative weather station with the NOAA River Forecast Center will be installed on the Harding Icefield, and a modeling project was funded to identify and prioritize areas for potential weather station deployment.

KEY REFERENCES:

Stenseth, N. C., A. Mysterud, G. Ottersen, J. W. Hurrell, K.-S. Chan, and M. Lima, 2002: Ecological effects of climate fluctuations. *Science,* 297, 1292-1296.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate is related to all other physical and biological issues and vital signs.

OVERALL ASSESSMENT: It is essential to understand the influence of climate variability on biotic and abiotic systems.

Geologic & Hydrologic Processes

Vital Sign 2: Lake and Coastal Ice

BRIEF DESCRIPTION: This vital sign refers to lake ice formation, contiguous ice cover, broken ice cover, ice thickness, and duration of ice cover. It also includes anchor ice that forms in coastal intertidal zones and estuaries as a result of tidal inundation.

SIGNIFICANCE: Lake ice is an important hydrologic variable that increases in significance with latitude and elevation, and produces a diverse array of impacts on physical, chemical, and ecological processes. Formation and movement of coastal sea ice may affect prey and predators directly by bulldozing intertidal habitats and controlling access to open water or preferred habitats; or indirectly, as changes in the sea-ice cover affect other species that serve as food. Lake ice formation, thickness and break-up are also key indicators of regional climate especially in data-sparse regions that characterize much of the network.

PROPOSED METRIC: annual duration and extent of coverage

RANK: overall 24, within category 2

TYPES OF MONITORING SITES: lakes, coastal shorezone

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: The presence of ice cover on the earth is relatively easy to detect from satellites due to the large change in a landscape's reflection, emission, and transmission characteristics.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: NOAA Pacific Alaska River Forecast Center has an observer network and database with records for Big River Lakes and Port Alsworth (LACL), King Salmon Creek (KATM) and two ice depth records for the Bradley River (near KEFJ).

KEY REFERENCES:

Liston, G.E. and Hall, D.K. 1995. Sensitivity of lake freeze up and break up to climate change: A physically based modeling study. *Ann. Glaciol*. 4:387-93.

Magnuson, J. et al. 2000. Historical trends in lake and river ice cover in the Northern Hemisphere. *Science*. 289(5485):1743-6.

Robertson, D.M. *et al.* 1992. Lake ice records used to detect historical and future climatic changes. *Climatic Change* 21:407-27.

Wynne, R.H. et al. 1998. Satellite monitoring of lake ice breakup on the Laurentian Shield (1980-1996). *Photo. Eng. Remote Sensing*. 64:607-18.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climatological conditions,

OVERALL ASSESSMENT: Dates of the formation of ice on inland water bodies in autumn and its melting in spring are a simple inexpensive means of tracking a key driver of ecological change in freshwater systems.

Vital Sign 3: Glacial Extent (advance, retreat)

BRIEF DESCRIPTION: Glacial extent refers to surface area coverage of ice on the land. Advance occurs when a mountain glacier's terminus extends farther down valley than previous measurements, while glacial retreat occurs when the position of a mountain glacier's terminus is farther up valley than previous measurements or when a glacier ablates more material at its terminus than it transports into that region (NSIDC 2003).

SIGNIFICANCE: Glaciers are highly sensitive, natural, large-scale, representative indicators of the energy balance of both mountains and lowlands within SWAN. Glaciers are often referred to as natural "water towers" because of their capacity to store water for extended periods and to exert control on the surface water cycle through timing of discharge, volume and variability, and delivery of sediments.

PROPOSED METRIC: glacier aerial extent

RANK: overall 15, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Methodological tools for efficiently tracking glacial extent include the analysis of satellite imagery, aerophotogrammetry and digital terrain information of various scales. Photo point documentation is commonly used for terminus monitoring. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING: Measurement of ice sheet margin may not provide timely information on volume changes.

CURRENT MONITORING: KEFJ has been monitoring the terminus position of Exit Glacier since 1987. The Geophysical Institute of the University of Alaska Fairbanks has conducted mass balance and volume change monitoring on Exit Glacier throughout the 1990's using airborne laser profiling techniques.

A glacial terminus photopoint project is being conducted by USGS in KEFJ in the summer of 2004, repeating photography taken by USGS glaciologist D.F. Higgins in 1909.

KEY REFERENCES:

Hambrey, M. 1994. *Glacial environments.* London, UCL Press.

Matthews, J.A., 1992. *The ecology of recently- deglaciated terrain: a geoecological approach to glacier forelands and primary succession.* Cambridge University Press.

Nesje, A. 1996. Geological indicators of rapid environmental change - glacier fluctuations and avalanche activity. In Berger, A.R. & W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems:* 17-32. Rotterdam: A.A. Balkema.

UNEP/GEMS, 1992. *Glaciers and the environment.* United Nations Environment Programme, Environment Library 9.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Glaciers are interrelated with virtually every physical driver in SWAN. Glacier forelands newly exposed in front of receding glaciers provide excellent natural laboratories to study plant succession and ecological relationships.

OVERALL ASSESSMENT: Fluctuations in glaciers are among the most sensitive indicators of climatic change. Knowledge of glacial changes is fundamental to understanding coastal, freshwater, and terrestrial ecosystems in SWAN.

Vital Sign 4: Snow Cover (area and phenology)

BRIEF DESCRIPTION: Snow cover refers to onset of snow accumulation, duration, and melt-off (disappearance). Snow cover duration determines the start and length of the growing season, and snow depth, structure and composition define subnivean temperatures and water and nutrient input.

SIGNIFICANCE: Snow is the dominant environmental factor in mountainous regions for more than half of the year. The properties of the snow cover influence the processes and species composition of subarctic ecosystems. Snow represents a major store of water which is released in the spring melt period and snow is an insulator that mediates the depths to which the soil freezes. In the alpine and subalpine, snow pack protects vegetation from the abrasive and dehydrating effects of wind, and wind driven snow, effectively limiting the height of woody vegetation to that of the snow pack. Snow also protects vegetation from excessive frost heaving. Vegetation community composition is strongly influenced by the relative duration of snow burial and exposure to wind and frost heaving.

PROPOSED METRIC: Landscape-scale patterning and duration of snow cover

RANK: overall 13, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Satellite coverage, weekly for annual coverage

LIMITATIONS OF DATA AND MONITORING: Like all components of the climate system, snow cover exhibits considerable variation from one year to the next in response to the natural variability of atmospheric circulation patterns which affect both snowfall and temperature.

CURRENT MONITORING: none, NRCS has four snow courses in Lake Clark and two in or near Katmai, but these measure snow accumulations and not area or phenology. A summary of all snow courses in Southwest Alaska has been completed:
http://www.nature.nps.gov/im/units/swan/Documents/Maps/SWAN_Weather_NRCS.pdf

KEY REFERENCES:

Brown, R.D., 2000: Northern Hemisphere snow cover variability and change, 1915-1997. *J. Climate* (in press).

Goodison, B.E. and A.E. Walker. 1993: Use of snow cover derived from satellite passive microwave data as an indicator of climate change. *Annals of Glaciology*, 17: 137-142.

Groisman, P. Ya, T.R. Karl, and R.W. Knight. 1994: Changes of snow cover, temperature and radiative heat balance over the Northern Hemisphere. *J. Climate*, 7, 1633-1656.

Robinson, D.A., K.F. Dewey and R.R. Heim. 1993. Global snow cover monitoring: an update. *Bull. Am. Meteorol. Soc.*, 74,, 1689-1696.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate, surface hydrology, vegetation composition and structure.

OVERALL ASSESSMENT: Snow cover duration is a valuable indicator of temporal variation in growing season for plants and the breeding season for birds in subarctic and alpine ecosystems. Studies on snow-vegetation interactions suggest that changes in snow cover have as important effects as changes in summer climate.

Vital Sign 5: <u>Stream Flow</u>

BRIEF DESCRIPTION: Streamflow refers to the volume of water passing a point of reference (discharge) and varies with precipitation, surface temperature, and other climatic factors. For most streams (rivers), the highest water discharge is found close to the sea.

SIGNIFICANCE: Streamflow directly reflects climatic variation. Stream systems play a key role in the regulation and maintenance of biodiversity. Changes in streams and streamflow are indicators of changes in basin dynamics and land use.

PROPOSED METRIC: Discharge

RANK: overall 29, within category 5

SPATIAL SCALE: basin/watershed

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: There are standard techniques for measuring streamflow. Where more quantitative data are not available, study of changes in biomass distribution (especially woody plants) can provide reliable qualitative measures of hydrologic and geomorphic events spanning the past several hundred years

LIMITATIONS OF DATA AND MONITORING: Streams in flood, and on deltas, and alluvial plains, such as glacial outwash, are difficult to gauge. The effectiveness of stream flow as an indicator depends strongly on a well- designed, systematic network of monitoring stations.

CURRENT MONITORING: KEFJ: Resurrection River, Exit Creek, Nuka R* LACL: Johnson River, Iliamna River*. Historical locations: KATM: Brooks River, Alagnak River, Eskimo Creek*; KEFJ: Nuka R, Bradley R*; LACL: Tanalian River, Tazimina*, Newhalen*, Kvichak*, Chakachamna* (* ouside park boundary). The location of USGS stream gaging stations in Southwest Alaska have been identified and summarized: http://www.nature.nps.gov/im/units/swan/Documents/Maps/SWAN_Weather_GagingStations.pdf

One of the products of a SWAN hydrographic modeling project, scheduled for completion in FY04, will be a list of potential stream gaging sites.

KEY REFERENCES:

Baker, V.R., R.C.Kochel & P.C.Patton (eds.) 1988. *Flood geomorphology* . New York: John Wiley and Sons.

Osterkamp, W.R. & S.A.Schumm 1996. Geoindicators for river and river-valley monitoring. In Berger, A.R. & W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems* :83-100. Rotterdam: A.A. Balkema.

Wolman, W.G. & H.C.Riggs 1990. *Surface water hydrology* . The Geology of North America, Volume 0-1, Boulder, CO: Geological Society of America.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Streamflow affects virtually all other environmental issues connected with water.

OVERALL ASSESSMENT: Streamflow is of fundamental importance to virtually all environmental monitoring.

Vital Sign 6: Stream and Lake Suspended Sediments

BRIEF DESCRIPTION: Suspended sediments are the load of sediment (in suspension and as bed load of silt, sand, and gravel) transported by streams into lakes and eventually into the sea. Loads of suspended sediment reflect upland erosion and glacial recession within the drainage basin and the volume of suspended sediment is primarily discharge dependent (Brabets 1997). In the spring, as streamflow increases, there is a corresponding increase in suspended sediment. Flow and sediment transport are maintained through the summer as glacial meltwater and rainfall runoff enter the river. In the fall, as glacial melt ceases, streamflow and suspended sediment declines.

SIGNIFICANCE: Changes in sediment load reflect changes in basin conditions, including climate, soils, erosion rates, vegetation, topography and land use. For example, high turbidity caused by glacial flour attenuates light, scours the substratum, and affects many freshwater ecosystem processes including primary productivity and structure of the biotic community. Changes in suspended sediment dynamics associated with glacial recession may force a biophysical regime shift in freshwater ecosystems that could affect focal species such as salmon.

PROPOSED METRIC: suspended sediment (turbidity), seasonal concentration, phenology, and patterns of distribution

RANK: overall 34, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Extensive: Satellite imagery has been effectively used to track suspended sediments because reflectance of water increases with increased suspended sediment concentrations. Intensive: Optical backscatterance sensors can be used to measure suspended-solids concentration (SSC) in surface waters. seasonal/annual

LIMITATIONS OF DATA AND MONITORING: Sediment discharge may increase or decrease due to natural cycles of stream development under conditions of stable climate.

CURRENT MONITORING: None

KEY REFERENCES:

Brabets, T. P. 1997. *Geomorphology of the lower Copper River, Alaska.* U.S. Geological Survey Professional Paper 1581, 89 p.

Guy, H.P. & V.W. Norman 1970. *Field methods for measurement of fluvial sediment.* US Geological Survey Techniques of Water Resources Investigation, Book 3, Chapter C-2.

Osterkamp, W.R. & S.A. Schumm 1996. Geoindicators for river and river-valley monitoring. In Berger, A.R. & W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems*:83-100. Rotterdam: A.A. Balkema.

Wolman, W.G. & H.C. Riggs 1990. *Surface water hydrology*. The Geology of North America Volume 0-1, Boulder, Colorado: Geological Society of America. (especially paper by Meade, R.H., T.R. Yuzyk & T.J. Day Movement and storage of sediment in rivers of the United States and Canada, p255-280).

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Stream sediment storage and load affects virtually all ecosystem functions in drainage basins and along coastlines fed by stream sediment.
OVERALL ASSESSMENT: Stream sediment storage and load is of extreme importance in determining the transport of erosion products through and out of drainage basins.

Vital Sign 7: River Channel Morphology

BRIEF DESCRIPTION: River channel morphology is the cross-sectional shape and longitudinal profile of a river and is the result of a complex interaction of the geologic setting, hydraulic factors, and environmental factors. Morphology of stream channels and types of pattern (braided, meandering, straight) and sinuosity are significantly affected by changes in flow rate and sediment discharge, and by the type of sediment load in terms of the ratio of suspended to bed load.

SIGNIFICANCE: Channel dimensions reflect magnitude of water and sediment discharges. In the absence of hydrologic and streamflow records, an understanding of stream morphology can help delineate environmental changes of many kinds. Changes in stream pattern, which can be very rapid in glacial streams, place significant limits on land use, such as on islands in braided streams and meander plains, or along banks undergoing erosion.

PROPOSED METRIC: Channel shape and profile

RANK: overall 37, within category 7

SPATIAL SCALE: mesoscale / regional

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Repeated ground and/or aerial surveys of channel patterns and cross- sections, using streamflow gauges, channel cross-section monuments, and other automated and manual loggers. Frequency depends on observed rate of change, but no less than once every 5 years.

LIMITATIONS OF DATA AND MONITORING: It is difficult to gauge stream change without historical records. Floods may destroy observation sites.

CURRENT MONITORING: In LACL cross-sections were measured at the Johnson River gaging site and as part of a 3-year study at 3 locations on the Crescent River. Historic cross-sections exist for the Tlikakila River.

KEY REFERENCES:

Chang, H.H. 1988. *Fluvial processes in river engineering*. New York: John Wiley & Sons.

Osterkamp, W.R. & E.R. Hedman 1982. *Perennial-streamflow characteristics related to channel geometry and sediment in Missouri River basin* . U.S. Geological Survey Professional Paper 1241.

Osterkamp, W.R. & S.A. Schumm 1996. Geoindicators for river and river-valley monitoring. In Berger, A.R. & W.J.Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems* :83-100. Rotterdam: A.A. Balkema.

Schumm, S.A. & B.R. Winkley (eds.) 1994. *The variability of large alluvial rivers* . New York: American Society of Civil Engineers Press.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Condition of riverine ecosystems; stability of islands and channels, and jurisdictional boundaries defined by rivers.

OVERALL ASSESSMENT: Monitoring stream channel morphology can be useful when no data are available on sediment load, flow rates and other hydrologic parameters.

Vital Sign 8: <u>Surface Water Hydrology</u> (Lake Levels)

BRIEF DESCRIPTION: Surface hydrology refers to water level (depth), aerial extent, timing of inundation, and water persistence. Some lakes receive their water mainly from precipitation, some are dominated by runoff from snowmelt and glaciers, and others are controlled by groundwater systems.

SIGNIFICANCE: Surface hydrologic factors account for more than 50% of the variation found in aquatic plant and animal populations (Keddy 2000). Lakes are dynamic systems that are sensitive to local climate and to land-use changes in the surrounding landscape. On a time scale ranging from days to millennia, the aerial extent and depth of water in lakes are indicators of changes in climatic parameters such as precipitation, radiation, temperature and wind speed. Records of lake dynamics in historic and pre-historic periods provide baseline data on past responses to climate change. With the establishment of threshold values, lakes may provide an early warning of shallow groundwater depletion.

PROPOSED METRIC: Extent and variability in surface water area (lake levels)

RANK: overall 27, within category 4

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Lake levels are generally measured with shoreline gauges. Areal extent is assessed primarily using successive air photos, supplemented with ground- level surveys, radar altimetry, and satellite images. Lake level and lake water composition monthly to annual. Areal extent every 5 years.

LIMITATIONS OF DATA AND MONITORING: Limited by availability of gauge data, resolution of photographic and satellite images, and by climatic records for baseline data. SWAN lakes show seasonal water level changes of up to 3 meters.

CURRENT MONITORING: None

KEY REFERENCES:

Gierlowski-Kordesch, E & K. Kelts (eds.) 1994. *Global geological record of lake basins.* Volume 1. Cambridge: Cambridge University Press.

Keddy, P.A. 2000. *Wetland ecology: principles and conservation*. Cambridge University Press, Cambridge.

Mason, I.M., M.A.J. Guzkowska, C.G. Rapley & F.A. Street-Perrott. 1994. The response of lake levels and areas to climate change. *Climatic Change* 27: 161-197.

Vance, R.E. & S.A. Wolfe 1996. Geological indicators of water resources in semi- arid environments: Southwestern interior of Canada. In Berger, A.R. & W.J. Iams (eds.). *Geoindicators: Assessing rapid environmental changes in earth systems*:237-250. Rotterdam: A.A. Balkema.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Lake levels are important for regional hydrological investigations, and for a wide range of issues concerning lakeshore land use.

OVERALL ASSESSMENT: Monitoring lake levels and extent provides a convenient and simple indicator of changes in climate and hydrological conditions.

Vital Sign 9: Coastal Shoreline Position

BRIEF DESCRIPTION: Shoreline position is the mean high water (MHW) contour, ideally found as "the intersection of the plane of mean high water with the shore." The position of the shoreline along ocean coasts varies over a broad spectrum of time scales in response to shoreline erosion (retreat) or accretion (advance), changes in water level, and land uplift or subsidence

SIGNIFICANCE: Changes in the position of the shoreline affect the composition, relative abundance, and distribution of coastal habitats. Shoreline position has jurisdictional implications for park management and affects cabins and other structures along the coast.

PROPOSED METRIC: Georeferenced position of the shoreline

RANK: overall 25, within category 3

SPATIAL SCALE: patch to mesoscale / network to regional

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Conventional ground survey and other methods (simple rod and tape profiles, leveling, electronic total-station surveys, air photos). GPS techniques are being developed to efficiently extract shoreline position from topographic data collected by airborne LIDAR, specifically NASA's Airborne Topographic Mapper (ATM). Seasonal, before and after storms. Semi-annual or annual, once seasonal variability is established

LIMITATIONS OF DATA AND MONITORING: Results can be site specific, temporally and spatially discontinuous. Changes in relative sea level and in sediment supply are critical factors in coastal evolution and in the response of shorelines to environmental change. In some cases sediment supply may be controlled by processes external to the coastal system, such as volcanic eruptions, glacier- burst floods, or changes in ice regimes.

CURRENT MONITORING: Twelve beach profiles transects (conventional ground survey methods) were established along the LACL coastline in 1992 and resurveyed in 1994.

KEY REFERENCES:

Berger, A.R. & W.J.Iams (eds.). 1996. *Geoindicators: Assessing rapid environmental changes in earth systems.* Rotterdam: A.A. Balkema. (see papers by Forbes & Liverman, Morton, and Young et al.).

Carter, R.W.G. 1988. *Coastal environments: an introduction to the physical, ecological and cultural systems of coastlines.* London: Academic Press.

Carter, R.W.G. & C.D. Woodroffe (eds.). 1994. *Coastal evolution: Late Quaternary shoreline morphodynamics.* Cambridge: Cambridge University Press. (especially paper by Cowell and Thom on coastal morphodynamics).

Godschalk, D.R., D.J. Brower & T. Beatley 1989. *Catastrophic coastal storms and hazard mitigation and development management.* Raleigh NC: Duke University Press.

Pilkey, O.H., R.A. Morton, J.T. Kelley & S. Penland 1989. *Coastal land loss.* Washington, American Geophysical Union.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Changes in the shoreline affect the distribution and functioning of salt marsh, estuarine and littoral ecosystems, as well as the planning and management of coastal resources and park facilities.

OVERALL ASSESSMENT: The shoreline position is perhaps the most important geoindicator for low-lying coastal shorelines and islands. Quantitative methods are best for predicting future shoreline movements. Qualitative indicators of shoreline position and morphology are practical, inexpensive, and rapid guides to coastal erosion.

Chemical

Vital Sign 10: Water Quality

BRIEF DESCRIPTION: The quality of surface water in rivers and streams, lakes, ponds and wetlands is determined by interactions with soil, transported solids (organics, sediments), rocks, groundwater and the atmosphere. It may also be significantly affected by industrial, mineral and energy extraction, urban and other human actions, as well as by atmospheric inputs.

Level 1 Core Field Parameters (dissolved oxygen, pH, specific conductance, water temperature, and discharge) provide instant information about the condition of a water body and also provide the metadata from which all other water quality parameters may be scientifically interpreted. They are required by the NPS Water Resources Division.

Level 2 Major Ions, which provide important geochemical data, include the dissolved cations of calcium, magnesium, sodium, and potassium and the major anions of sulfate, chloride, and those contributing to alkalinity. **Nutrients** (nitrogen, ammonia, phosphorus, and potassium), while essential for animal and plant growth, can, in excess, indicate undesirable eutrophication or the presence of animal wastes in water bodies. These nutrients are frequently very low in SWAN water bodies. Chlorophyll-a is a representation of the productivity of the water body, while DOC (dissolved organic carbon) integrates watershed and water body productivity, since much of the carbon is allochthonous. DOC is generally proportional to the amount of wetlands in a watershed, and is affected by climate change. DOC in many of the streams in Aniakchak, and in Surprise Lake, was below the detection level of the technique used. **Trace Elements** (including arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) occur naturally only in minor amounts but easily become toxic to biota if their concentrations in water and sediments are increased due to anthropogenic activities. Silicon and iron are geo-chemical indicators.

SIGNIFICANCE: The chemistry (quality) of water reflects inputs from the atmosphere, from soil and water-rock reactions (weathering), as well as from pollutant sources such as mining, land clearance, acid precipitation, domestic and industrial wastes.

PROPOSED METRIC: Specific metrics will depend upon parent material, water body type, and stressor evaluation. Concurrent discharge measurements would allow data to be flow rated.

RANK: overall 18, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Sampling and analysis for water quality determination varies with site conditions and the constituents to be measured.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Level 1 indicators are currently being collected at Johnson River in LACL.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: There are many causes of changes in the quality of surface water, including acid precipitation, residential development, mining, and volcanic eruptions.

OVERALL ASSESSMENT: Surface water quality is one of the most fundamentally important environmental variables to be monitored. It is also of value as an indicator of short-term improvement or deterioration in the environment.

Vital Sign 11: Air Quality (IMPROVE)

BRIEF DESCRIPTION: Air Quality refers to the presence and concentrations of various pollutants in the ambient air. The Interagency Monitoring of Protected Visual Environments Program (IMPROVE) is a long-term, cooperative visibility monitoring effort among the EPA, NOAA, NPS, USFS, USFWS, and state air agencies. For aerosols, measurements include particle size, and the mass concentrations of aerosol species that include sulfates, nitrates, organic carbon, inorganic carbon, earth crustal components, ions, and other major and trace elements.

SIGNIFICANCE: Poor air quality affects both natural environments and human health.
SWAN park units are exposed to potential air pollution through long range transport from the Far East, through passing air and ship traffic, from local sources such as wood burning stoves or diesel generators, and through proximity to industrial development, such as the hydrocarbon industry in Cook Inlet. Air pollution has been shown to cause lake acidification, vegetation change, and changes in nutrient cycling.

PROPOSED METRIC: aerosols

RANK: overall 35, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: The IMPROVE site uses air compressors to pump air from the outside through a series of filters. These filters collect particulate matter that is suspended in the atmosphere including sulfur, nitrogen, hydrogen, carbon, and metals such as zinc, lead, and mercury. Frequency: continuous

LIMITATIONS OF DATA AND MONITORING: Air quality conditions at IMPROVE monitoring sites at Tuxedni Channel and Simeonof may have limited spatial relevance to parks in the networks and expanding the number of stations may be prohibitively expensive.

CURRENT MONITORING: None by NPS in SWAN park units. The U.S. Fish and Wildlife Service has an IMPROVE site on the Cook Inlet coast at a private inholding within the Lake Clark boundary, and a second site on the Simeonof Islands, which may be representative of the Aniakchak airshed. An IMPROVE station was operated at King Salmon from 1987-1993.

KEY REFERENCES:

Eldred, R.A., Cahill, T.A., Wilkenson, L.K., et al. Measurements of fine particles and their chemical components in the IMPROVE/NPS networks, in Transactions of the International Specialty Conference on Visibility and Fine Particles, Air and Waste Management Association: Pittsburgh, PA, 1990; pp 187-196.

Improve website: http://vista.cira.colostate.edu/improve/

Alaska Improve data:
http://vista.cira.colostate.edu/improve/Web/MetadataBrowser/MetadataBrowser.aspx?StateCode=AK&Program=IMPROVE&Measure=Aerosol

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Oil and gas operations, mining, sensitive vegetation communities

OVERALL ASSESSMENT: Air quality monitoring reveals trends in the quantity of significant pollutants in the atmosphere by documenting the highest average concentration recorded during the year. Knowing these maximum values is useful because the potential adverse effects of contaminants on plants and animals usually increase with its concentration.

Vital Sign 12: Earthquake Activity (Frequency, Intensity)

BRIEF DESCRIPTION: Earthquake activity refers to frequency, magnitude and location of earthquakes in southcentral Alaska.

SIGNIFICANCE: Earthquakes can result in temporary or permanent changes in the landscape, depending on the magnitude of the earthquake, the location of its epicenter, and local soil and rock conditions. Earthquake surface effects include uplift or subsidence, surface faulting, landslides and debris flows, liquefaction, ground shaking, and tsunamis (`tidal' waves caused by undersea tremors). Alaska is characterized by high seismicity due to the active subduction of the Pacific plate beneath the North American plate (~5-7 cm/year), and is the most seismically active region in the United States by a large margin. Numerous faults run through SWAN parks, including the Castle Mountain/Lake Clark/Bruin Bay fault complex within LACL, and the Aleutian Megathrust fault which arcs along the northern Gulf of Alaska, offshore of Kenai Fjords, Katmai and Aniakchak.

PROPOSED METRIC: location, date, and magnitude

RANK: overall 32, within category 3

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Specific locations (latitude, longitude and location), date (month, day, year), time, depth (m) and magnitude (according to the Richter scale) are available through the Alaska Earthquake Information Center. Frequency: continuous

LIMITATIONS OF DATA AND MONITORING: Monitoring seismicity will identify where earthquakes are likely to occur and their potential magnitude, but not when they might be expected, nor any physical effects, such as subsidence or uplift.

CURRENT MONITORING: The Alaska Earthquake Information Center (AEIC) operates a seismic network of more than 300 seismic stations distributed throughout Alaska, receiving and archiving waveform data from all stations in near-real-time. The National Park Service (NPS) is considering a proposal by the U.S. Geological Survey -Alaska Volcano Observatory (AVO) to improve seismic monitoring networks in SWAN. In Katmai National Park three new digital seismic stations would be installed and three existing analog seismometers would be upgraded to the new digital technology. In Lake Clark National Park, two analog seismometers on the flanks of Redoubt Volcano would be upgraded to the new digital technology. In Aniakchak National Monument a single station would be converted to the new digital technology. The new technology greatly improves the detection of seismic activity indicative of volcanic activity, and would lead to timely hazard forecasts to protect the general public.

KEY REFERENCES:

Cox T., and R. Hansen. **Seismic Networks in Alaska**,
http://www.giseis.alaska.edu/Seis/html_docs/fact_sheets.html

Page, R.A., N.N. Biswas, J.C. Lahr, and H. Pulpan. 1991. Seismicity of Continental Alaska, *in* Slemmons, D.B., E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., Neotectonics of North America: Boulder, Colorado, Geological Society of America, Decade Map Volume 1.

Labay, K, and Haeussler, P.J. 2001. *GIS Coverages of the Castle Mountain Fault, South Central Alaska.* U.S. Geological Survey Open-File Report 01-504

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS:

OVERALL ASSESSMENT: Understanding earthquake activity is basic to understanding geologic processes that created and maintain network landscapes and seascapes.

Vital Sign 13: Volcanic Activity (Frequency, Intensity)

BRIEF DESCRIPTION: Volcanic activity refers to all the actions (geophysical, geochemical and neo-tectonic) that occur before, during and after an eruption. Eruptions are almost always preceded and accompanied by volcanic unrest, indicated by variations in the geophysical and geochemical state of the volcanic system. Such geoindicators commonly include changes in seismicity, ground deformation, nature and emission rate of volcanic gases, fumarole and/or ground temperature, and gravity and magnetic fields. Volcanic unrest can also be expressed by changes in temperature, composition, and level of crater lakes, and by anomalous melting or volume changes of glaciers and snow fields on volcanoes.

SIGNIFICANCE: Volcanic eruptions have shaped the landscape of SWAN parks for thousands of years, and indirectly, the flora and fauna and their distribution. Ash may smother vegetation, but depending on chemical composition, may also enrich the soil as well as aquatic systems. Ash also has detrimental effects on wildlife: fall from the 1931 eruption of Aniakchak reportedly killed reindeer and caribou at Nushagak, and swans and geese at Ugashik (Hubbard, 1932). Landslides induced by the 1912 Novarupta eruption may have barriered Dakavak Lake, preventing access by returning sockeye and creating a new kokanee population.

Other volcanic hazards, such as lava flows, pyroclastic flows, floods, and tsunamis, are of lesser concern for human risk, since SWAN volcanoes do not occur in immediate proximity to major population centers. However, flooding from the 1966 eruption of Redoubt nearly engulfed the Drift River oil tanker terminal, located on the coastal lowlands below the volcano. Of historical interest, the 1912 Novarupta eruption in Katmai forced the abandonment of Katmai village.

PROPOSED METRIC: Frequency, intensity

RANK: overall 17, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Seismometers, satellite data

LIMITATIONS OF DATA AND MONITORING: Volcanic effects, such as depth and aerial extent of ash or lava flows, will not be monitored.

CURRENT MONITORING: The Alaska Volcano Observatory (AVO) monitors seismic activity in real time at 24 volcanoes, including the following volcanoes in or near SWAN park units: Spurr, Redoubt, Iliamna, Augustine, Snowy, Griggs, Katmai, Novarupta, Trident, Mageik, Martin, and Aniakchak, In addition, AVO monitors volcanoes in Alaska and Kamchatka using Polar Orbiting and Geostationary satellite data. These systems include visible, infrared and microwave wavelength data.

KEY REFERENCES:

Ewert, J.J. & D.A.Swanson (eds.). 1993. *Monitoring volcanoes: techniques and strategies used by the staff of the Cascades Volcano Observatory 1980-1990* . U.S. Geological Survey Bulletin 1966.

McGuire, B., C.R.J. Kilburn & J. Murray (eds.). 1995. *Monitoring active volcanoes: strategies, procedures and techniques.* London: University College London Press.

Scarpa, R. & R.I. Tilling 1996. *Monitoring and mitigation of volcano hazards.* Berlin: Springer-Verlag.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: A major volcanic eruption has implications on all vital signs at the park or network scale.

OVERALL ASSESSMENT: Volcanic activity is of major ecological and management concern and much of the infrastructure for monitoring this vital sign is already in place.

Vital Sign 14: <u>Insect and Disease Outbreaks</u>

BRIEF DESCRIPTION: Insect outbreak refers to cyclic patterns of abundance of insects that kill or damage woody plants by feeding on leaves and burrowing into stems and trunks.

SIGNIFICANCE: Outbreaks of insects such as the spruce bark beetle (*Dendroctonus rufipennis*) can result in widespread changes in forest landcover. This can alter habitats through changes in hydrology (HDR Alaska Inc. 1998), changes in woody debris inputs to streams, and changes and long-term shifts in wildlife habitat availability. For example, Harlequin ducks and river otters might experience positive short-term benefits as a result of a potential increase in nesting/denning sites created by dense undergrowth and downed wood. Bald eagles and marbled murrelets would experience a decrease in suitable nest sites where spruce is the dominant tree.

PROPOSED METRIC: Species, timing and area of occurrence

RANK: overall 19, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: annual aerial surveys

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: The Alaska Department of Natural Resources (DNR) conducts aerial surveys each summer jointly with the U.S. Forest Service, Forest Health Protection and Alaska DNR, Division of Forestry to assess forest condition statewide.

KEY REFERENCES:

Fastie, C. L.; Berg, E. E.; Swetnam, T. W. 1999. The response of boreal forests to lethal outbreaks of spruce bark beetles on the Kenai Peninsula, Alaska.

HDR Alaska, Inc. 1998*. Hydrologic Analysis of the Funny River and Russian River Watersheds Using the Distributed Hydrology-Soil-Vegetation Model (DHSVM*). Report prepared for The Nature Conservancy of Alaska.

Matthews, K., compiler. 1997. Forest Health Protection Report: Forest Insect and Disease Conditions in Alaska-1997. U.S. Department of Agriculture, U.S. Forest Service. General Technical Report R10-TP-70. 62p.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Vegetation community composition, climatological measurements

OVERALL ASSESSMENT: Insect and disease outbreaks can be extremely important disturbance factors; during outbreaks, woody vegetation is often killed over vast areas. Under climate change, damage patterns caused by insects and disease may change considerably, particularly those of insects whose temporal and spatial distributions strongly depend on climatic factors.

Freshwater Biota

Vital Sign 15: <u>Resident Fish</u>

BRIEF DESCRIPTION: The structure of a fish community is defined by the species present, their relative abundances, their life stages and size distributions, and their distributions in space and time.

SIGNIFICANCE: Fish possess several attributes of a good environmental indicator: they represent a variety of trophic levels (omnivores, insectivores, planktivores, and piscivores); have variable habitat requirements; extensive information is available on the biology and needs of many species; they integrate changes and disturbances that occur in the food chain; they are easy to collect and identify; and they lend themselves to the measurement of chronic or acute conditions caused by toxic substances. They are also of interest to decision-makers and the general public because of their economic and recreational value. Local extinction, range extension, or deviation in life-history strategies may result from minor changes in the physical or biological characteristic of freshwater habitat. These changes will in turn affect interspecies interactions such as competition, predator-prey relationships, and habitat partitioning.

PROPOSED METRIC: Composition, abundance, & distribution

RANK: overall 23, within category 2

SPATIAL SCALE: mesoscale / network/ park

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Commonly used survey techniques such as minnow traps, seines, electroshockers, gill nets, and fyke nets, will be used in conjunction with mark-recapture and other relevant estimators. Sampling at decadal frequency or as other vital signs suggest that changes may have occurred.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: No current monitoring. The current fish survey, as well as earlier work, has established baseline presence information on resident fish communities for selected water bodies within SWAN park units.

KEY REFERENCES:

Bayley, P. B., and J. T. Peterson. 2001. An approach to estimate probability of presence and richness of fish species. Transactions of the American Fisheries Society 130:620-633.

Kwak, T. J., and J. T. Peterson. In Press. Community indices, parameters, and comparisons. In M. Brown and C. Guy, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Fish community structure is related to all hydrogeological processes.

OVERALL ASSESSMENT: Because fish are of such economic and ecological importance, it is important to understand the condition of the fish community in lakes and rivers. This is useful in identifying watersheds where the fish community may be showing signs of impairment and can aide management in directing monitoring and protection activities.

Vital Sign 16: Salmon (Abundance)

BRIEF DESCRIPTION: Salmon abundance refers to the numbers of naturally spawning adult salmon returning to spawning areas.

SIGNIFICANCE: Sockeye salmon are a keystone species in the SWAN aquatic and terrestrial ecosystem. Nutrients from spawned-out salmon carcasses appear to play an important role in sustaining the productivity of riparian and lacustrine ecosystems including the perpetuation of future salmon runs (Kline et al. 1990, Gende et al. 2002, Schindler et al. 2003). Determination of adult spawner abundance information is a critical aspect of monitoring and protecting viable populations of this resource.

PROPOSED METRIC: Abundance of adult spawners (annual escapement or index to escapement)

RANK: overall 1, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Aerial surveys, tower counts, weirs, sonar. Frequency: annual.

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: ADF&G has been monitoring escapement for all five species of salmon in the Aniakchak and Meshik River system through aerial surveys, and at Delight Lake through the use of a weir. ADF&G also maintains a counting tower for sockeye on the Naknek River, just outside the Katmai boundary. Crescent River escapement has traditionally been monitored by ADF&G through the use of a sonar site, although this site may be discontinued. For the past three years, USGS BRD has maintained a counting tower at a historic (1980-1984) U. of Washington Fisheries Research Institute tower site on the Newhalen River, but it is unlikely that this site will be funded in 2004. Finally, the Alagnak River escapement has been periodically monitored by ADF&G with special project money.

KEY REFERENCES:

Cederholm, C.J., D. H. Johnson, R. E. Bilby, L. G. Dominguez, A. M. Garrett, W. H. Graeber, E. L. Greda, M. D. Kunze, B. G. Marcot, J. F. Palmisano, R,. W. Plotnikoff, W. G. Pearcy, C. A. Simenstad, and P. C. Trotter. 2000. Pacific Salmon and Wildlife-Ecological Contexts, Relationships, and Implications for Management. Special Edition Technical Report. Prepared for D. H. Johnson and T. A. O'Neil (Managing directors), Wildlife Habitat Relationships in Oregon and Washington. Washington Department of Fish and Wildlife, Olympia, WA.

Gende, S. M., R. T. Edwards, M.F. Willson, and M.S. Wipfli. 2002. Pacific salmon in aquatic and terrestrial ecosystems. BioScience. 52:917-928.

Kline, T.C., J.J. Goering, O.A. Mathisen, and P.H. Hoe. 1990. Recycling of Elements Transported Upstream by Runs of Pacific Salmon: ^{15}N and ^{13}C Evidence in Sashin Creek, Southeastern Alaska. Can. Jour. Fish. Aquat. Sci. 47:136-144.

Schindler, D.E., M.D. Scheuerell, J. W. Moore, S. M. Gende, T. B. Francis, and W. J. Palen. 2003. Pacific salmon and the ecology of coastal ecosystems. www.frontiersinecology.org. Accessed February 11, 2004.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Salmon influence the seasonal distribution and abundance of birds and mammals that prey on them (Cederholm et al 2000).

OVERALL ASSESSMENT: Salmon escapement (records of abundance of adults that complete their life cycle, and return to spawning grounds) provides crucial information on the state of marine, aquatic, and terrestrial ecosystems.

Vital Sign 17: Beaver (Presence and Distribution)

BRIEF DESCRIPTION: Beaver presence and distribution refers to the existence and location of active beaver colonies across park landscapes.

SIGNIFICANCE: Beaver ponds in various stages of creation and decay form a shifting mosaic of diverse vegetation communities across watersheds, playing a major role in shaping the landscape. The actions of beavers can influence temporal changes in stream flow, wetland size and hydroperiod, which consequently affects aquatic plants and animals. The occurrence of many aquatic animals such as loons, swans, river otter, and wood frogs is correlated with the presence of beaver ponds. Consequently, the presence of beavers is an indicator of biodiversity.

PROPOSED METRIC: Presence and distribution of active lodges

RANK: overall 30, within category 3

SPATIAL SCALE: basin / watershed

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: aerial surveys or photography. Frequency: 3-5 yrs

LIMITATIONS OF DATA AND MONITORING: Active beaver colonies tend to be cyclical, but some causes for these cycles may be related to human influence as well as changes in population of competitors for woody plants, predators and climate.

CURRENT MONITORING: None

KEY REFERENCES:

Johnston, C.A. and R.J. Naiman. 1990. The use of a geographic information system to analyze long-term landscape alteration by beaver. Landscape Ecology 4: 5-19.

Johnston, C.A., J. Pastor and R.J. Naiman. 1993. Effects of beaver and moose on boreal forest landscapes. pp. 236-254. In S.H. Cousins, R. Haines-Young, and D. Green (eds.) Landscape Ecology and Geographical Information Systems. Taylor & Francis, London.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: surface hydrology, wetland plants and animals. salmon occurrence

OVERALL ASSESSMENT: The presence or absence of active beaver ponds indicates the presence or absence of distinctive plants and animal assemblages (biodiversity) across park landscapes.

Vital Sign 18: Aquatic Birds (Selected Species Presence and Distribution)

BRIEF DESCRIPTION: Selected aquatic bird species include, but are not limited to, Trumpeter Swans (Cygnus buccinator), Harlequin Ducks (Histrionicus histrionicus), loons, American Dippers (Cinclus mexicanus) and Belted Kingfishers (Megaceryle alcyon).

SIGNIFICANCE: These species have similar foraging characteristics and habitat needs that make them sensitive to changes in aquatic ecosystem habitat quality and availability. They will likely be among the first species to respond to changes associated with surface hydrology, glacier retreat, climatic warming, and bioaccumulated toxins.

PROPOSED METRIC: occurrence and distribution

RANK: overall 33, within category 4

TYPES OF MONITORING SITES:

SPATIAL SCALE: basin / watershed

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: ground surveys for non-waterfowl, aerial surveys for waterfowl. Frequency: 3-5 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Trumpeter swans as part of USFWS state-wide surveys at 5-year intervals. Harlequin Ducks have been surveyed in LACL and KATM (Bennett 1996, Goatcher et al. 1999).

KEY REFERENCES:

Bennett, A.J. 1996. Physical & Biological Resource Inventory of the Lake Clark National Park-Cook Inlet Coastline, 1994-96. Lake Clark National Park and Preserve Kenai Coastal Office. Kenai, AK. 137 pp.

Gilbertson, M. 1990. Freshwater avian and mammalian predators as indicators of environmental quality. Environmental Monitor. Assess. 15(3):219-224.

Goatcher, B., Zwiefelhofer, D. and K. Scribner. 1999. Differentiation and Interchange of Harlequin Duck Populations Within the North Pacific. Exxon Valdez Oil Spill Trustee Council Restoration Project No. 97161, Final Report

MacKenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. Ecology 84:2200-2207.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Surface hydrology, river channel morphology, glacier retreat, sensitive vegetation communities, salt marsh, vegetation composition and structure, landcover.

OVERALL ASSESSMENT: Aquatic birds are ideal for use as an ecological indicator because their presence or absence tends to signal the status of conditions that are key to the proper functioning of aquatic ecosystems. Furthermore, this relationship is often associated with levels of human disturbance. In addition to providing an overall signal of ecosystem health, birds are also ideal because they are relatively easy to sample and their natural history is well described relative to other taxonomic groups in wetland ecosystems.

Marine Biota

Vital Sign 19: Shorezone Habitat

BRIEF DESCRIPTION: Shorezone habitats are distinctive features created by a combination of shoreline geomorphology and nearshore oceanic processes. Habitats include sand and mudflats, bedrock platforms, rocky intertidal, tidal marshes, river deltas, sand spits, beach and backshore areas, banks and bluffs, and marine riparian areas. These habitats are described and depicted in the Coastal Scoping Workshop Summary.
http://www.nature.nps.gov/im/units/swan/Documents/Workshops/CoastalWorkshop_sum.pdf
SIGNIFICANCE: The volume, composition, and interaction among habitats is partly responsible for maintaining trophic structure and productivity of the nearshore. There are strong physical and biological linkages in the shorezone that force predictable patterns in biological communities. The condition of the biota depends in part on the quality of the physical-chemical environment of estuaries and coastal marine waters; i.e., habitat. Habitat is in turn influenced by natural and catastrophic events, climate, and other factors including discharges, which contribute materials (sediment, nutrients, contaminants) to the water body. Information on the quality, quantity, and distribution of intertidal habitats is important to monitoring and protecting park coastlines.

PROPOSED METRIC: Composition and volume

RANK: overall 3, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: habitat mapping using tidally-coordinated aerial photography and targeted ground truthing. Frequency: 10 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: ShoreZone maps of all network parks 2001-2003. LACL coastal atlas 1995. ESI data for all parks.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Relative sea level, shoreline position, seagrass, marine invertebrates.

KEY REFERENCES:

Exxon Valdez Oil Spill Trustee Council. 2002. Detecting and Understanding Change in Nearshore Environments: Planning for Habitat Mapping in the Gulf of Alaska

Mann, D.H. 1996. Shore-Zone classification of Katmai National Park and Preserve and Kenai Fjords National Park. Report To National Park Service. Coop Agreement 14-48-0009-1582. 5 pgs.

Schoch, G.C., G.L. Eckert and T.A. Dean. 2002. Long-Term Monitoring in the Nearshore: Designing Studies to Detect Change and Assess Cause. EVOS Project Number 02395. Workshop summaries and recommendations:, Project Number: 02395, Workshop Summaries and Recommendations, November 9, 2001, Santa Barbara, California, January 24, 2002, Anchorage, Alaska.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Salt marsh, ice cover, sediment load

OVERALL ASSESSMENT: Monitoring changes in the volume and composition of shorezone habitats is pivotal to understanding and predicting changes in nearshore biodiversity that result from natural and human-related events.

Vital Sign 20: Saltmarsh

BRIEF DESCRIPTION: Salt marshes are distinctive coastal vegetated ecosystems where the upper elevation of occurrence is approximately the highest astronomical tide, while the lower limit is rarely below mean high water neap. In SWAN they occur as large extensive areas along the broad intertidal flats of KATM and LACL and smaller "pocket beach" marshes along deep fjords in KEFJ.

SIGNIFICANCE: Salt marshes are among the most productive ecosystems in the world and play a critical role in the ecology of SWAN coastal areas. Salt marshes filter terrestrial run-off, act as sinks for nutrients and greenhouse gases, provide nursery and feeding habitat for fish and shellfish species, and support large concentrations of brown bears and waterfowl. As an ecological indicator, salt marshes have long been viewed by ecologists as the model example of an ecosystem controlled by "bottom-up factors", e.g. nutrients and physical factors (Kennish 2001).

PROPOSED METRIC: Extent and composition**,** sediment accumulation rate

RANK: overall 10, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: habitat mapping using tidally-coordinated aerial photography and targeted ground truthing. Numerous protocols are available for salt marsh monitoring. Frequency: 10 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Salt marshes were mapped and classified at LACL in 1994.

KEY REFERENCES:

Kennish, M. J. 2001. Coastal Salt Marsh Systems in the U.S.: A Review of Anthropogenic Impacts. Journal of Coastal Research 17(3): 731-748. McAlister, W.H. and M.K. McAlister. 1995. Aransas: A naturalist's guide. University of Texas Press, Austin, Texas. USA

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: tectonic uplift, glacier retreat, sediment dynamics, relative sea level, brown bears.

OVERALL ASSESSMENT: Monitoring the response of salt marshes to environmental factors such as shoreline position, sea level rise, changing salinity, and human actions is crucial to understanding and protecting park coastlines.

Vital Sign 21: Kelp and Eelgrass

BRIEF DESCRIPTION: Eelgrass (*Zostera marina*) grows in beds (clusters) in low energy intertidal and shallow subtidal sandy mudflats. Kelp beds containing species such as split kelp (*Laminaria bongardiana*), bull kelp (*Nereocystis luetkeana*), brown algae *(Alaria fistulosa* and *Agarum cribrosum*), and ribbon or wing kelp (*Alaria crispa*) grow in rocky substrates.

SIGNIFICANCE: Kelp and eelgrass are "living habitats" that serve as a nutrient filter, provide understory and ground cover for planktivorous fish, clams, urchins, and a physical substrate for invertebrates, crustose corals, and algae. Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone (from high water to the depth of light penetration) kelps produce nearly 75% of the net carbon fixed. Eelgrass and many species of kelp have been declining world wide. Oil spills have negative effects on *Nereocystis* communities, and *Alaria* beds in the Aleutians are currently receding because of grazing by urchins. Other stresses include activities that disturb the beds directly such as dredging and anchor scars, events that reduce the ability for light to penetrate into the water column, such as runoff (increased turbidity) or nutrient addition. Mumford and others (1995) called for the subtidal populations to be surveyed as indicators of changes in water quality

PROPOSED METRIC: Presence and distribution (aerial extent)

RANK: overall 21, within category 5

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Eelgrass and kelp is monitored in many regions as an indicator of nearshore habitat quality by comparing maps of resource abundance and distribution over time. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING:

KEY REFERENCES:

Asmus, H., & Asmus, R. 1999. The role of intertidal seagrass beds - organisms and fluxes at ecosystem level. Report of workshop of 7-13th August 1998. ECSA Bulletin, 30, 21-29.

The Partnership for Interdisciplinary Study of Coastal Oceans. Oregon State University, Stanford University, University of California Santa Barbara, and University of California Santa Cruz, http://www.piscoweb.org/

Intertidal Monitoring Program. Minerals Management Service, Ventura, California, http://www.mms.gov/omm/pacific/enviro/mint.htm

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, marine invertebrates, suspended sediments, oil spills, sea otter, water quality, land-use change and habitat alteration.

OVERALL ASSESSMENT: Seagrass habitat is a sensitive (nonresilient) indicator of shallow coastal intertidal and subtidal ecosystems because it is characterized and maintained by a biological matrix rather than physical structures or processes alone.

Vital Sign 22: <u>Marine Intertidal Invertebrates</u> (Soft Sediment Infauna)

BRIEF DESCRIPTION: Intertidal invertebrate community composition refers to species richness, species relative abundances, and heterogeneity of their spatial or temporal distributions. "Abiotic factors" known to influence community composition refers to sediment type, grain size and sorting; water quality parameters; and sediment organic properties (Total Organic Carbon and Total Nitrogen).

SIGNIFICANCE: Intertidal mudflats and sandflats support highly productive habitats and populations of littleneck clams (*Protothaca staminea*), surf clams (*Mactromeris polynyma)*, macomas (*Macoma* spp.), soft shelled clams (*Mya* spp.) and other invertebrates. These invertebrates, in turn, provide a critical prey resource for shorebirds, ducks, fish, bears, sea otters (*Enhydra lutris)*, and other marine invertebrate predators, as well as spawning and nursery habitats for forage fish and juvenile crustaceans. In addition to their trophic importance, bottom (benthic) organisms possess many characteristics that make them useful indicators of environmental stress in the nearshore marine environment. They have a wide range of physiological tolerances and feeding and reproductive modes, and therefore have the potential to respond to a wide array of environmental stressors. Because benthic organisms are relatively sedentary, they cannot escape sediment contamination. For these reasons, benthic organisms often show measurable responses to environmental stress.

PROPOSED METRIC: composition and distribution of dominant assemblages; and abiotic factors known to influence species composition, distribution, and abundance

RANK: overall 16, within category 3

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Changes in intertidal invertebrate assemblages can be assessed from time series analysis of species counts obtained from regular quadrat sampling. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING: Interpreting the CAUSES of change is often an experimental design issue and cannot be reached via simple monitoring.

CURRENT MONITORING: Individual surveys of benthic infauna in or near network parks have been done in the past, but most involved spatially-limited descriptive analysis of species presence, generally in connection with some existing or planned perturbation (off-shore oil and gas leases, Exxon Valdez Oil Spill, dredging).

KEY REFERENCES:

Roman, C., R. Irwin, R. Curry, M. Kolipinski, J. Portnoy, L. Cameron. 2003. White-Paper Report of the Park Service Vital Signs Workgroup for Monitoring Marine and Estuarine Environments. Workgroup Convened April 3-4, 2002, North Atlantic Coast CESU at the University of Rhode Island, Narragansett, RI,. IN REVIEW, **http://www.nature.nps.gov/im/monitor/COREparam.doc.**

Strayer, D. L., and D. R. Smith. 2003. A guide to sampling freshwater mussel populations. American Fisheries Society Monograph No. 8, Bethesda, Maryland.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Aquatic birds, relative sea level, suspended sediment, sea otters, harbor seal, contaminants

OVERALL ASSESSMENT: Changes in the abundance, diversity, biomass and species composition of intertidal invertebrates can indicate important changes in the coastal environments of which they are a part, and can have effects that cascade to other trophic levels.

Vital Sign 23: <u>Sea Otter and Harbor Seal</u>

BRIEF DESCRIPTION: Sea otter and harbor seal presence and distribution refers to locations of occurrence, patterns of distribution, and relative abundance. Sea otter and harbor seals are one of the most common marine mammals in the Gulf of Alaska (GOA), where they occur throughout the year.

SIGNIFICANCE: Sea otters are the textbook example of a "keystone" predator. Sea otters dramatically change the structure and complexity of their nearshore ecological community. The relationship between sea otters and kelp is a prime example of the top-down cascade type of food chain where the highest trophic level can determine the populations of the lower trophic levels. Like sea otters, harbor seals perform a dynamic role in the nearshore by transferring nutrients and energy and by regulating the abundance of other species. They may play a structural role by influencing the physical complexity of their environment; or they may synthesize the marine environment and serve as indicators of ecosystem change. Sea otters and seals are a key part of the marine ecosystem, and they are an important resource for Alaska Natives, for the tourism industry, and for everyone who enjoys watching wildlife.

PROPOSED METRIC: Distribution and relative abundance

RANK: overall 20, within category 4

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Sea otters and harbor seals have been surveyed using a wide variety of methods (ground counts, boat surveys, and various aerial surveys). Monitoring protocols exist for sea otter and harbor seal in the northern Gulf of Alaska. Frequency: 1-3 yrs

LIMITATIONS OF DATA AND MONITORING: Each method has inherent biases.

CURRENT MONITORING: The USFWS surveyed portions of the Pacific coast of the Alaska Peninsula in 1992 and 2000.

KEY REFERENCES:

Bodkin, J. L, K. A. Kloecker, G. G. Esslinger, D. H. Monson, DeGroot, J. D., and J. Doherty. 2002. Sea otter studies in Glacier Bay National Park and Preserve. 2001 Annual Report. U.S. Geological Survey, Biological Resources Division, Anchorage, AK.

Bodkin, J. L. and D. H. Monson. 1999. Sea otter distribution and relative abundance, Cross Sound - Icy Strait survey summary. U.S. Geological Survey, Biological Resources Division, Anchorage, AK.

Frost, K. J., L. F. Lowry, R. J. Small, and S. J. Iverson. 1996. Monitoring, habitat use, and trophic interactions of harbor seals in Prince William Sound, Alaska. Exxon Valdez Oil Spill Restoration Project Annual Report (Restoration Projects 95064), Alaska Department of Fish and Game, Division Wildlife Conservation, Fairbanks, AK. 87 pp + appendices.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Coastal shorezone habitat, climate change, kelp and eelgrass, marine invertebrates, marine debris and animal carcasses, bioaccumulated toxic contaminants.

OVERALL ASSESSMENT: Sea otters and harbor seals are an indicator of the health of the nearshore marine ecosystem because they tend to be relatively sedentary in comparison to other marine mammals; eats large amounts of food; incidence of disease is correlated with contaminants; and they have broad appeal to the public.

Vital Sign 24: River Otter

BRIEF DESCRIPTION: River otter occurrence, distribution, and relative abundance based on field sign survey techniques.

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SIGNIFICANCE: River otters in coastal environments of Alaska tend to select habitats close to the shore, where their chief food items are marine bottom-dwelling fishes (Larsen 1983, Bowyer et al. 1994). In the aftermath of the *Exxon Valdez* oil spill (EVOS), studies of coastal river otters (*Lontra canadensis*) in Prince William Sound indicated that they are a keystone species for the land-margin ecosystem and a "sentinel species" for monitoring levels of environmental contamination (Bowyer et al. 2003).

PROPOSED METRIC: occurrence, distribution, and relative abundance

RANK: overall 26, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: An index to abundance can be generated by surveying and documenting the distribution and use of latrine sites (Bowyer et al. 2003). Frequency: 2-5 yrs

LIMITATIONS OF DATA AND MONITORING: This technique may not have relevance along coastlines where otters have access to extensive riverine and freshwater wetland habitats. The current distribution of coastal river otter is not known in the SWAN. Moreover, the reliability of indices for monitoring trend is suspect.

CURRENT MONITORING: Prince William Sound and KEFJ

KEY REFERENCES:

Bowyer, R. T., W. J. Testa, and J. B. Faro. 1995. Habitat selection and home ranges of river otters in a marine environment: effect of the Exxon Valdez oil spill. Journal of Mammalogy 76:1-11.

Bowyer, R. T., G. M. Blundell, M. Ben-David, S. C. Jewett, T. A. Dean, and L. K. Duffy. 2003. Effects of the *Exxon* Valdez oil spill on river otters: injury and recovery of a sentinel species. Wildlife Monographs 153: 1–53.

Golden, H. N., and M. Ben-David. *In preparation*. Monitoring river otter latrines to index population trends: is it a reliable tool? Journal of Mammalogy 000: 000–000.

Larsen, D. N. 1983. Habitats, movements, and foods of river otters in coastal southeastern Alaska. Thesis, University of Alaska Fairbanks, Fairbanks, Alaska, USA.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, surface water hydrology, water quality, salmon, resident fish, bioaccumulated toxic contaminants

OVERALL ASSESSMENT: Coastal river otters are a resource limited species that may signal changes in productivity of the nearshore.

Vital Sign 25: Seabirds (Kittiwakes, Guillemots, Gulls, Kittlitz murrelet)

BRIEF DESCRIPTION: Seabirds are long-lived organisms that spend most of their lives at sea but nest on coastal cliffs and islands in colonies, usually of several species. Colonies occur along the coasts of all network parks.

SIGNIFICANCE: Seabirds respond to their marine environment over a variety of temporal and spatial scales and serve as indicators of ecological change in the nearshore marine environment (Golet et al. 2001, Diamond and Devlin 2003). Seabirds are predators near the top of marine food webs. Their abundance and population trends reflect the dynamics of the processes that maintain the integrity of the marine nearshore environment. For example, long-term studies have demonstrated that population size, breeding success and survival of black-legged kittiwakes (Rissa tridactyla) integrate changes in the marine ecosystem from sea-surface temperature through plankton and fish, over decadal time-scales (Aebischer et al, 1990). The Kittlitz's murrelet (Brachyramphus brevirostris) is a rare seabird that nests in alpine terrain and generally forages near tidewater glaciers during the breeding season. Affinity to tidewater glaciers (of which the lower elevation glaciers are receding rapidly) are reasons for concern about the long-term conservation of Kittlitz's murrelets Survey data from two core areas (Prince William Sound and Glacier Bay) suggest that populations have declined by 80-90% during the past 10-20 years.

PROPOSED METRIC: Occurrence, size, productivity of colonies- Kittiwakes, Guillemots, Gulls

RANK: overall 31, within category 7

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Established protocols exists. Frequency: 5-10 yrs

LIMITATIONS OF DATA AND MONITORING: CURRENT MONITORING: The U.S. Fish and Wildlife Service currently monitors selected seabird colonies throughout coastal Alaska, including Chiswell and Chisik Island colonies, off shore of KEFJ and LACL.

KEY REFERENCES:

Aebischer, N.J., J.C. Coulson, and J.M. Colehsook. 1990. Parallel long-term trends across four marine trophic levels and weather. Nature 147:753-755

Dimond A.W. and C.M. Devlin. 2003. Seabirds as indicators of changes in marine ecosystems: ecological monitoring on Machias Seal Island. Environmental Monitoring and Assessment 88:153-175

Golet, G. H., D. B. Irons, and D. P. Costa. 2000. Energy costs of chick rearing in Black-legged Kittiwakes. *Canadian Journal of Zoology* 78:982-991.

Golet, G. H., P. E. Seiser, A. D. McGuire, D. D. Roby, J. B. Fischer, K. J. Kuletz, D. B. Irons, T. A. Dean, S. C. Jewett, S. H. Newman. 2001. Long-term direct and indirect effects of the Exxon Valdez oil spill on Pigeon Guillemots in Prince William Sound, Alaska. *Marine Ecology Progress Series*. In press.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, surface water hydrology, water quality, salmon, resident fish, bioaccumulated toxic contaminants

OVERALL ASSESSMENT: Seabirds nest in colonies which are easy to locate and relatively straightforward to count; species exploit prey at specific trophic levels, allowing changes to different parts of the food-web to be detected within a single community; and techniques for estimating population size, and in many cases productivity, are well established.

Terrestrial Biota

Vital Sign 26: Landscape Patterns

BRIEF DESCRIPTION: Landscape pattern refers to the arrangement of species and communities in a natural setting. Vegetation structure is the dominant life form of the community: forest, shrubland, tundra or barrens. More subtle changes in vegetation communities are reflected in their composition: the presence and relative occurrence of plant species in a community. This vital sign would track the changes in patterns of vegetation type and community structure across the landscape such as advancing timberline, alder invasion, or loss of lichen ground cover.

SIGNIFICANCE: Land cover and its spatial patterns are key ingredients in ecological monitoring that considers large regions and changes from natural and human-related events. Landscape pattern and vegetation communities integrate biotic and environmental factors in their structure and composition. Vegetation communities can reflect long term trends in climate, biotic interactions, or human uses. Climate trends would show as trees advancing into subalpine or down the Alaska Peninsula, or invading drying marshlands. Changes in biotic interaction may show as loss of lichen cover in the ground layer, or alder invading willow communities.

PROPOSED METRIC: Land cover classes, plant community composition and structure (special focus on treeline, shrub/alder, Sphagnum expansion)

RANK: overall 4, within category 2

SPATIAL SCALE: landscape / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: remote sensing data, site visits, possible combination of methods across a random or systematic set of samples. Frequency: decadal

LMITATIONS OF DATA AND MONITORING: Variations in satellite sensors and classification procedures may be greater than actual variation in vegetation composition. Protocols need to be carefully developed to evaluate change over long term. Needs to be combined with other indicators.

CURRENT MONITORING: Baseline vegetation maps have been prepared for Lake Clark and Katmai; maps for Kenai Fjords and Aniakchak are in process.

KEY REFERENCES:

Gustafson, E. J. 1998. Quantifying landscape spatial pattern: what is the state of the art? Ecosystems 1:143-156

Wickham, J. D. and D. J. Norton. 1994. Mapping and analyzing landscape patterns. Landscape Ecology 9:7-23.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate change, glacial extent, snowcover, surface water hydrology, earthquake activity, volcanic activity, fish, birds, mammals, land-use change and habitat alteration.

OVERALL ASSESSMENT: Monitoring vegetation and landscape patterns is of fundamental importance to an integrated ecological monitoring program because changes in the amount and configuration of habitat controls the occurrence, distribution, and abundance of animals.

Vital Sign 27: <u>Sensitive Vegetation Communities</u>

BRIEF DESCRIPTION: This vital sign refers to vegetation communities which reflect environmental change more rapidly than the general landscape. Wetlands are very sensitive to differences in level and duration of surface moisture. Sitka spruce die off rapidly with salt water intrusion, and recolonize when salts have been leached from coastal soils. Sensitive communities would include salt and freshwater marshes, bogs/fens, supra-tidal zones, kettle lakes, alpine and subarctic timberline and glacial refugia.

SIGNIFICANCE: Some vegetation communities reflect environmental change faster than others. While changes may be occurring on landscape or ecosystem scales, their actual effects show up more rapidly in sensitive communities. Changes in species composition and areal extent or spatial location often indicate subtle changes in controlling environmental factors. Detecting changes in sensitive communities alerts managers to underlying trends at larger scales. Targeting selected sensitive communities at mesoscales helps to provide an “early warning system” for landscape level changes. Sites may include:

Alpine areas, subalpine ecotones, mountain tops
Aquatic areas (wetlands and emergent vegetation, bogs, kettle lakes)
Snowmelt areas
Refugia (ice-free or ash free zones in glacial or volcanic landscapes)
Treeline sites (alpine and subarctic)
Riparian zones
Periglacial zones
South-facing steppe bluffs
Volcanic deposition areas

PROPOSED METRIC: vascular and non-vascular species composition (presence and frequency/cover), areal extent of community, spatial locations

RANK: overall 11, within category 4

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Actual methods would vary with the selected community. Generally, permanent plots would be periodically visited for data collection including plant species composition and site environmental factors. Large scale aerial photographs would be used to map changes in areal extent and location. Frequency: 5-10 year

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: USFWS has been monitoring potholes and marshes in the Kenai Wildlife Refuge. Baseline mapping for coastal salt marshes in Lake Clark was done in 1995.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Monitoring sensitive communities will indicate changes in tectonic uplift and subsidence, ground water levels and climate.

OVERALL ASSESSMENT: Changes in sensitive communities signal changes at greater spatial scales and because they are often nodes of high biodiversity signal changes in obligate plants and animals.

Vital Sign 28: <u>Brown and Black Bear</u> (Population Composition and Human-Related Killings

BRIEF DESCRIPTION: Brown and black bear population composition refers to relative abundance and sex and ratios at concentration areas. In Alaska it is legal to kill a bear in defense of life or property (DLP). Over 1,000 brown and black bears were killed in Alaska in defense of life or property between 1990 and 2001 (ADF&G unpubl). DLP killing are increasing throughout Alaska wherever human populations and resource development activities are expanding.

SIGNIFICANCE: Brown bears are excellent wilderness ecosystem indicator species because of key biological traits: a) they have few young; b) they range over large areas; c) they occur at low population densities; and d) they are prone to direct conflict with people. The combination of these biological traits interacting with people's proclivity to develop and use brown bear habitat usually results in compromised brown bear populations and habitat. As omnivores and apex predators, brown bears are one of the first species to be lost from an area as a result of land development activities. As human-bear interactions increase, mortality from DLP and other causes may exceed sustainable levels. Although legal hunting can be managed, DLP and illegal kills are difficult to manage in rural communities.

PROPOSED METRIC: DLP number, location, bear age, and sex

RANK: overall 2, within category 1

SPATIAL SCALE: park

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Index counts at concentration areas, state DLP records, annual

LIMITATIONS OF DATA AND MONITORING: Index counts may not reflect population-level changes. Unreported kills are difficult to estimate.

CURRENT MONITORING: State records. Effort underway by Research and Biological Resources Team (NPS-Alaska Region) to develop a historical database of bear-human interactions including DLP killings in some SWAN parks.

KEY REFERENCES:

Boulanger, J., G. C. White, B. N. McLellan, J. Woods, M. F. Proctor, and S. Himmer. 2003. A meta-analysis of grizzly bear DNA mark-recapture projects in British Columbia. Ursus 13:137-152.

Miller, S. G., et al. 1997. Brown and black bear density estimation in Alaska using radiotelemetry and replicated mark-resight techniques. Wildlife Monographs 133:1-55.

Using DNA for long-term monitoring. Workshop on Ecological and Conservation Applications of Bear Genetics, Workshop summary on International Association for Bear Research and Management Web site: http://www.bearbiology. com

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Salmon, ungulates, saltmarsh, vegetation composition and structure, visitor use.

OVERALL ASSESSMENT: Human land-use, depletion of salmon resources, and recreational growth are factors that can adversely affect bears and, in doing so, signal a loss of environmental quality affecting many species.

Vital Sign 29: <u>Large and Medium Carnivores</u> (Wolf, Wolverine, Lynx, Marten)

BRIEF DESCRIPTION: This vital sign refers to presence/absence and for some species may include relative abundance (density).

SIGNIFICANCE: Carnivores are important indicators of ecosystem integrity in National Parks in that they influence the structure and reflect the vigor of the trophic levels upon which they depend (Eisenberg 1989, Garrett L. K. and R. G. Wright. 2000). Because they are wide-ranging predators, habitat specialists, and dispersal limited species, they are also sensitive to the abundance and behavior of the humans with which they coexist. They are important components of ecosystems contributing to competition, resource partitioning and the overall structure of both herbivore and carnivore guilds. They are effective indicators because they reflect the terrestrial cumulative effects of changes in habitat, prey populations, and human harvest.

PROPOSED METRIC: presence/absence and relative abundance (density)

RANK: overall 12, within category 5

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: remote cameras, snow tracking transects and visual indices.

LIMITATIONS OF DATA AND MONITORING: These species are shy, inconspicuous, primarily nocturnal, and occur at low population densities.

CURRENT MONITORING: Pilot surveys occurring in 2004 on some species within SWAN.

KEY REFERENCES:

Becker, E. F., M. A. Spindler, and T. O. Osborne. 1998. A population estimator based on network sampling of tracks in the snow. Journal of Wildlife Management 62:968–977.

Garrett L. K. and R. G. Wright. 2000. Prioritizing the Research and Monitoring Needs of Terrestrial Mammals in National Parks. The George Wright Forum 17(1):80-92

Zielinski, William J.; Kucera, T.E. 1995 American Marten, Fisher, Lynx, and Wolverine: Survey Methods for Their Detection U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station; Gen. Tech. Rep. PSW-GTR-157: 163p.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Ungulates, vegetation composition and landscape patterns, resource harvest, land-use change and habitat alteration,

OVERALL ASSESSMENT: Large and medium carnivores are symbols of wilderness, and thriving populations serve as a indicator of naturally functioning wild ecosystems.

Vital Sign 30: Landbirds (Composition and Distribution Patterns)

BRIEF DESCRIPTION: Landbirds are smaller birds (exclusive of raptors and upland game birds) not usually associated with aquatic habitats. By contrast, aquatic birds include loons, waterfowl, and other surface water-dependent species.

SIGNIFICANCE: Birds select habitats based on their suitability, which makes them very useful as indicators of environmental changes. Landbirds respond to changes over many spatial scales. Their occurrence and reproductive success have been shown to be influenced by the nature and configuration of surrounding habitats. Most landbird species are dependent on specific habitat attributes, and habitat alterations, such as those brought about by natural disturbance or human activities, have considerable potential to affect landbird communities

From a sampling perspective, land birds are one of the best tools for monitoring because: 1) they are the most easily and inexpensively detected and identified vertebrate animals, 2) a single survey method can cover many species, and 3) accounting for and maintaining many species with different requirements promotes conservation strategies at the landscape scale (Hutto and Young 2002)

PROPOSED METRIC: occurrence, species richness, distribution

RANK: overall 38, within category 7

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT:

LIMITATIONS OF DATA AND MONITORING: A linkage of bird populations and habitat changes (both natural and human-caused) is dependant upon our ability to measure both components.

CURRENT MONITORING: MAPS (Monitoring Avian Productivity and Survival) stations were operated in KATM in the mid-90's, and SWAN initiated a montane bird inventory project in 2003.

KEY REFERENCES:

Cam, E., J. D. Nichols, J. R. Sauer, and J. E. Hines. 2002. On the estimation of species richness based on the accumulation of previously unrecorded species. Ecography 25:102-108.

Hines, J. E., T. Boulinier, J. D. Nichols, J. R. Sauer, and K. H. Pollock. 1999. COMDYN: software to study the dynamics of animal communities using a capture-recapture approach. Bird Study 46(suppl.):S209-S217.

Hutto, R. L., and J. S. Young. 2002. Regional landbird monitoring: perspectives from the northern Rocky Mountains. Wildlife Society Bulletin 30:738-750.

Rosenstock, S. S., D. R. Anderson, K. M. Giesen, T. Leukering, and M. F. Carter. 2002. Landbird counting techniques: current practices and an alternative. Auk 119:46-53.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climate change, vegetation composition and structure, land-use change and habitat alteration, insects outbreaks and disease.

OVERALL ASSESSMENT: Monitoring selected landbirds across habitats may be among the most cost-effective methods of assessing a broad-based element of ecosystem status in network parks.

Vital Sign: 31 Ungulates (Distribution, Patterns)

BRIEF DESCRIPTION: Ungulates in SWAN can include moose, caribou, Dall sheep and mountain goats. Distribution pattern refers to seasonal or resident occurrence across the landscape.

SIGNIFICANCE: The occurrence, distribution and seasonal movements of large ungulates and their predators are an ecologically defining element of the SWAN landscape. Ungulates are an important food source for many avian and mammalian predators including humans. During cycles of high abundance, they have the potential to influence the structure and function of the terrestrial ecosystems (Naiman 1988). Ungulate distribution patterns are anticipated to change in response to climatic changes that influence habitats.

PROPOSED METRIC: Distribution patterns

RANK: overall 9, within category 3

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Direct (aerial) counts, indirect observation of sign (ground plots). 1-3 years

LIMITATIONS OF DATA AND MONITORING: Landscape scale distribution pattern may not signal localized population declines.

CURRENT MONITORING: ADF&G, NPS, and the U.S. Fish and Wildlife Service (USFWS), cooperatively work on surveying moose trend areas in Aniakchak and along the Park and Preserve boundary in Katmai, while NPS carries out moose trend surveys in the Lake Clark Preserve. Ideally, each area is surveyed every one to three years, but poor snow and weather conditions have sometimes hampered efforts to survey trend areas. Lake Clark has surveyed Dall sheep at 5-10 year intervals. ADF&G surveys the Mulchatna and Northern Alaska Peninsula caribou herds on an annual basis.

KEY REFERENCES:

Naiman, R. J. 1988. Animal influences on ecosystem dynamics. *BioScience* 38:750-752.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Brown and black bear, large and medium carnivores, human harvest, land-use change and habitat alteration.

OVERALL ASSESSMENT: Monitoring large-scale changes in distribution patters of ungulates signals movement bottlenecks, reproductive sinks, habitat changes, or other factors that could adversely affect metapopulation dynamics. Ungulates are of key ecological importance and are highly valued by humans.

Vital Sign: 32 Bald Eagle (Occurrence and Productivity)

BRIEF DESCRIPTION: Bald Eagle occurrence and productivity refers to nest locations, rates of occupancy, and rates of reproductive success.

SIGNIFICANCE: Bald Eagle occurrence and reproductive performance is an indicator of seasonal prey abundance, weather conditions, toxic contaminants, and human-related disturbance. Bald Eagles are ecologically significant because they can be keystone predators that regulate other bird populations. For example, juvenile eagles raid cormorant and kittiwake breeding colonies by scaring adults off their nests, and either taking young directly or allowing ravens and crows to gain access to nests.

PROPOSED METRIC: occupancy, reproductive success

RANK: overall 22, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Traditional monitoring methods for bald eagle breeding/nesting populations involve annual completion of 2 temporally separate surveys (collectively designated productivity surveys) to determine: 1) occupancy, and 2) results of all breeding attempts in the population. Frequency: annual

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Active or intermittent monitoring at KATM, KEFJ and LACL. State-wide monitoring on national wildlife refuges and national forests.

KEY REFERENCES:

Anthony, R.G., M.G. Garrett, and F.B. Isaacs. 1999. Double-survey estimates of bald eagle populations in Oregon. Journal of Wildlife Management 63(3): 794-802

Bednarz, J.C. and K. Steenhof. 1999. The bald eagle; review of past monitoring efforts and suggestions for the future. pp. 56-57. . Raptor Research Foundation Annual Meeting, program and abstracts, November 3-7, 1999, La Paz, Baja California, Sur, Mexico.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Environmental contaminants, salmon, snow cover, climatological conditions, resident fish, and visitor use, seabirds.

OVERALL ASSESSMENT: The Bald Eagle is widely distributed in SWAN, respond rapidly to environmental changes, and is one of the most studied birds in North America. Monitoring protocols exist along with a great amount of natural life-history information, including the affects of various stressors on eagle reproductive performance.

Human (Stressors)

Vital Sign 33: Land Use Change and Habitat Alteration (Due to Human Activities)

BRIEF DESCRIPTION: Land use change is a shift to a different land use or an intensification of an existing one. Land use changes can result in physical, chemical, or biological alterations of habitat, or injury to, plants animals and other components of the ecosystem. This vital sign would track effects of human use in the region on the (mostly) natural landscapes of the network. Particular foci would be changes in access patterns and methods, resource development in the region, including offshore developments, subsistence patterns, and activities associated with private in-holdings in and near park lands.

SIGNIFICANCE: Human activities have great potential to cause rapid, long term and permanent changes to ecosystems of SWAN. Land use change causes loss or alterations in habitat, biodiversity, and biogeochemical cycles. Alteration or fragmentation of ecosystems can hinder movements and dispersal of plants and animals. Species that require large, unbroken expanses of habitat are often most sensitive to the effects of fragmentation. In some cases, the effects of fragmentation on sensitive species are a direct result of changes in the size and arrangement of suitable habitats across the landscape. In others, impacts are due mainly to more frequent interactions of species with humans, or predators, or to other factors associated with an intruding land use.

PROPOSED METRIC: location and extent of human activities (i.e. access routes, structures)

RANK: overall 8, within category 3

SPATIAL SCALE: miniscale/ network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: public records, NPS patrols, media. Frequency: annual.

LIMITATIONS OF DATA AND MONITORING: will need some systematic protocol to detect new or expanding activities

CURRENT MONITORING: Nothing systematic, beyond normal park management activities and patrols

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: water quality, air quality, sensitive vegetation communities, brown and black bear DLPs, large and medium carnivores, shorezone habitat, ungulates, visitor use, exotic species, resource harvest for subistence and sport.

OVERALL ASSESSMENT: Monitoring land use change by humans provides a direct measure of the near-field stressor most likely to have widespread and long-term adverse affects on park ecosystems.

Vital Sign 34: <u>Visitor Use</u> (Type, Level and Distribution)

BRIEF DESCRIPTION: This vital sign will address the number of visitors and their type of use by geographic area within park units. Day use is defined as individuals that use backcountry areas but do not remain overnight. This would include lodge guests as well as rental cabin use, and other self directed day use individuals. Backcountry overnight use is the number of individuals who use backcountry areas within park boundaries and do stay overnight.

SIGNIFICANCE: Human presence can have unexpected and significant effects on ecosystems and ecosystem processes. On a small scale, trampling increases erosion, and decreases habitat for small mammals (loss of cover, loss of food) and aquatic organisms (increased invertebrate drift, destruction of biofilm, loss of aquatic macrophytes). Human use can serve as a vector for exotic species and through habitat change, decreased competitive ability of resident species. Heavy use can fragment the landscape for sensitive wildlife, modify wildlife behavior through conditioning, and lead to over fishing, or over harvest in focal areas. Human waste can add significant nutrients to often nutrient poor environments, and further tip the balance in favor of exotic species .

Data about visitor use is important because of the driving force humans have on ecosystems. Not only are total numbers of visitors important in understanding overall usage of park resources, but understanding the trends in visitor use can aid managers in minimizing the impacts of humans on sensitive animals and ecosystems.

PROPOSED METRIC: Over all visitor use, day use or overnight, geographic area of use, type of use,

RANK: overall 6, within category 1

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT:

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Concessionaire permits require an annual activity report, which may contain some of this information.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Land-use change and habitat alteration, access, resource harvest, brown and black bear, freshwater fish, and exotic species.

OVERALL ASSESSMENT: Monitoring visitor use parameters provides basic information that park managers need to protect both park resources and visitor experience from impacts associated with visitor use, and provides context for the interpretation of visitor-related changes in other resources addressed by vital signs monitoring.

Vital Sign 35: Resource Harvest for Subsistence and Sport

BRIEF DESCRIPTION: Annual number and type of subsistence and sport harvest, and in Aniakchak, Katmai Preserve and Lake Clark. (Subsistence use is not allowed in Kenai Fjords, nor in Katmai National Park.) Sport wildlife harvest in Aniakchak, Katmai, and Lake Clark Preserves; subsistence gathering and sport fish take throughout all park units.

SIGNIFICANCE: The Alaska National Interest Lands Claim Settlement Act (ANILCA) of 1980 established by statute that subsistence hunting, fishing, and gathering would be legitimate activities on some 41,458,000 acres of new parklands, including lands within Aniakchak, Katmai, and Lake Clark. ANILCA also allowed sport harvest within Preserves; sport fishing is allowed in any National Park unit. Subsistence harvest regulations and bag limits are often more liberal than sport harvest, and have the potential for depressing wildlife populations in local areas, such as around human population centers or access routes. Brown bears are of particular concern, since they have low reproductive rates, yet in some park units, subsistence regulations allow for the annual take of one bear per subsistence hunter.

PROPOSED METRIC: State/Federal harvest records for sport and subsistence fish and wildlife take. Federal Special Use Permits for house log and firewood cutting.

RANK: overall 7, within category 2

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Frequency: annual

LIMITATIONS OF DATA AND MONITORING: Harvest records are collected by both state and federal agencies, but no central database exists. State harvest units are large, and do not conform to park boundaries, so park specific harvest cannot be determined. Harvest records may not be representative of actual harvest. Although illegal harvest is assumed to be low within park boundaries, unreported harvest is often high, especially within Alaska.

CURRENT MONITORING: State and Federal agencies currently collect this data.

KEY REFERENCES:

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Ungulates, predators, brown and black bear, salmon, resident fish, land-use change, landscape patterns and vegetation composition and structure.

OVERALL ASSESSMENT: Subsistence and sport harvest parameters are a direct measure of human effects on species and ecosystems.

Vital Sign 36: Marine Debris and Animal Carcasses (Type, Frequency of Occurrence)

BRIEF DESCRIPTION: Marine debris refers to commercial fishing gear, galley waste and other trash from ships, recreational boaters, and offshore oil and gas exploration and production facilities. Animal carcasses refers to beach cast marine birds and mammals.

SIGNIFICANCE: Marine debris from commercial fishing gear is a chronic problem on SWAN coastlines. Debris washed ashore diminishes the scenic value of beaches, and while adrift or onshore can endanger marine wildlife. Marine debris also collects and transports oil and other pollutants onto beaches. Of particular concern is fishing gear and plastic debris which when discarded at sea can entangle and kill marine mammals, birds, and fish.

Beach cast carcass surveys have delivered useful information on the state, causes and the extent of die offs related to marine pollution and other causes. Usually the first sign of impact from spilled oil is the appearance of dead and dying birds and marine mammals on beaches.

PROPOSED METRIC: Debris: type, location, and frequency of occurrence
Carcasses: species, location, and if available sex, age, cause of death

RANK: overall 36, within category 6

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Beach transects. Protocols available for the Gulf of Alaska. Frequency:2-4 yrs

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Marine debris surveys conducted at KATM in 1993-94.

KEY REFERENCES:

Ribic, C.A., T.R. Dixon, and I. Vining. 1992. *Marine Debris Survey Manual*. NOAA Technical Report NMFS 108. U.S. Department of Commerce, Springfield, VA

USEPA. 1998a. *Coastal Watersheds*. EPA 842-F-98-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC. www.epa.gov/owow/oceans/factsheets/fact1.html., http://www.epa.gov/epahome/exitepa.htm, http://www.epa.gov/epahome/exitepa.htmAccessed April 2002.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Shorezone habitat, oil spills, ship groundings, visitor use, exotic species, land-use change and habitat alteration.

OVERALL ASSESSMENT: Marine debris monitoring provides a relatively inexpensive window into offshore events such as animal moralities and discharge of pollutants and provides baseline data for use during natural resource damage assessments after oil spills.

Vital Sign 37: <u>Bioaccumulated Toxic Contaminants</u> (Type and Level of Concentration)

BRIEF DESCRIPTION: Bioaccumulation refers to the increase in concentration of a pollutant from the environment to an organism. Biomagnification refers to the increase in concentration of a chemical over time as it passes upward through the food chain. Bioaccumulated toxic contaminants are chemical compounds such as organochlorines (DDT, PCB, dioxins, and other related chemicals), volatile and semivolatile organic compounds (components of gasoline, fuel oils, and lubricants, organic solvents, fumigants, some inert ingredients in pesticides), and toxic trace elements (arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc). These chemicals are not readily metabolized or eliminated by organisms so concentrations increase with exposure.

SIGNIFICANCE: Since World War II, man made chemical compounds have proliferated, and are increasingly found in the environment. Many are easily transported over long distances by air, or water. and studies have shown that salmon can be a vector for introducing organic pollutants into freshwater systems (Kremmel et al. 2000). These chemicals can be toxic, but also exhibit sub-lethal effects such as behavioral changes, genetic mutation, abnormal grown and reproductive failure.

PROPOSED METRIC:

RANK: overall 28, within category 5

SPATIAL SCALE: mesoscale / network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT:

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: None. In 1996, the Cook Inlet Regional Citizens Advisory Committee established baseline contaminant levels for *Macoma balthica* in Chinitna and Tuxedni Bays (Cook Inlet RCAC 1996). Contaminant analysis included polycyclic aromatic hydrocarbons, alkyulated homologues, trace metal analysis, and bivalve condition index. Frenzel (2000) analyzed sediment from the Kamishak (KATM) and Johnson Rivers (LACL) for organochlorines, semivolatile organic compounds and trace elements, including arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc. Organochlorines were not detected. Frenzel (2000) also analyzed slimy sculpin from the Kamishak River for trace elements. Lake Clark National Park and Preserve has an active proposal for measuring mercury in northern pike

KEY REFERENCES:

Cook Inlet RCAC. 1996. Lake Clark National Park Bivalve Study – Data Report. Kinnetic Laboratories, Inc. 7pgs.

Kremmel, E. M., R.W. Macdonald, L.E. Kimpe, I. Gregory-Eaves, M. J. Demers, J. P. Smol, B. Finney, and J. M. Blais. 2000. Delivery of pollutants by spawning salmon. Nature 425:255-256

Frenzel, S. 2000. Selected organic compounds and trace elements in streambed sediments and fish tissues, Cook Inlet Basin, Alaska. U.S. Geological Survey Water Resources Investigations Report 00-4004.

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Atmospheric deposition of pollutants, oil spills, visitor use, land-use change and habitat alteration, bald eagle productivity, freshwater fish, marine invertebrates, marine debris and animal carcasses.

OVERALL ASSESSMENT: Monitoring bioaccumulated toxic contaminants is organisms such as freshwater fish and marine invertebrates are an indicator for habitat exposure to organic and inorganic contaminants. It is a direct measure of variation in chemical contaminants between sites, and contributes to the understanding of trends in contamination in SWAN.

Vital Sign 38: Exotic Species

BRIEF DESCRIPTION: An exotic species is any plant or animal that is not native (indigenous) to Southwesten Alaska. Exotic species monitoring will track non-native plant and animal species which are introduced in and near network parklands, whether intentionally or accidentally.

SIGNIFICANCE: Exotic species have the potential to disrupt native biological communities by competing with native species for space, food, and other resources; or by preying upon native species, especially juveniles. Of greatest immediate concern is the SWAN marine coastline. Vessels traveling the world's oceans pick up "hitchhiking" flora and fauna on their hulls and in their ballast water tanks. Resurrection Bay-Seward, Kachemak Bay-Homer, and the Kodiak Harbor have a high potential for invasions because they receive cruise ships, oil tankers, wood-chip, and other boat traffic from outside of Alaska. Hines and Ruiz (2002) recently identified 21 nonindigenous marine species in the Homer Harbor. Most commercial tour boats that visit SWAN are moored in Homer, Seward, or Kodiak.

Similarly, many private and commercial floatplanes that land in freshwater lakes originate in Anchorage, Homer, or Kodiak. These aircraft and their human passengers provide an avenue of transport for exotic plants and other organisms to reach remote regions of the parks. Increasing visitation rates, developments on private inholdings, and the general warming trend in climate all favor the likelihood of exotic species becoming introduced and established in network parks.

PROPOSED METRIC: non-native species occurrence and distribution

RANK: overall 14, within category 4

SPATIAL SCALE: focal sites across network

PROSPECTIVE METHOD(S) AND FREQUENCY OF MEASUREMENT: Protocols are available to survey and record exotic plant species. Exotic invertebrates, animals, fish and birds will need similar protocols. Frequency: annual to decadal

LIMITATIONS OF DATA AND MONITORING:

CURRENT MONITORING: Exotic plant surveys have been started in Katmai and Kenai Fjords. http://www.nature.nps.gov/im/units/swan/Documents/ReportsMonitoring/Phase_I_Report/AppendixJ_Exotic_Species_Threats.pdf

KEY REFERENCES:

Alaska Department of Fish and Game. 2002. Alaska aquatic nuisance species management plan. Juneau, AK. 103 pp

Hines A H. and G. M. Ruiz. 2002. Marine Invasive Species and Biodiversity of South Central Alaska Unpubl., Smithsonian Environmental Research Center, Edgewater, Maryland

RELATED ENVIRONMENTAL ISSUES AND LINKED VITAL SIGNS: Climatological conditions, insect and disease outbreaks, landscape patterns and vegetation composition, sensitive vegetation communities, land-use changes.

OVERALL ASSESSMENT: The destination of boats, aircraft, and people within SWAN corresponds to habitats that are also the most hospitable for the establishment of exotic species, i.e., coastal bays and estuaries, freshwater lakes and wetlands.